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Leaving the Beaten Tracks in Creative Work – A Design Theory for Systems that Support Convergent and Divergent Thinking

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Abstract

Existing knowledge is a vital prerequisite for creativity. It provides a central source of inspiration for new ideas and determines the pathways available for creative problem solving. Notwithstanding its indisputable role, knowledge may also compromise creativity. The human mind is prone to reproduce what it is used to, and the provision of explicit knowledge constitutes a potential inhibitor of imagination. Hence, IT systems supporting creative work have to support creative individuals by extending their personal knowledge while, at the same time, preventing them from merely walking down beaten tracks. In this article, grounded in theory on human cognition and literature on creativity support, we propose a design theory for IT systems that support both convergent and divergent thinking, that is, the central cognitive processes in creative work. We provide details on a prototypical implementation, discuss an illustrative case from the creative industries in order to demonstrate the design's applicability, and outline plans for an empirical evaluation of the proposed design theory.

***Keywords**: Creativity, Creativity Support Systems, Design Theory, Convergent Thinking, Divergent Thinking.*

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Leaving the Beaten Tracks in Creative Work – A Design Theory for Systems that Support Convergent and Divergent Thinking

1. Introduction

Creativity is an indispensable factor in propelling economic growth in modern societies (Amabile & Khaire, 2008). It drives the process that leads to the production of products, services, and processes that are both novel and purposeful (Woodman, Sawyer, & Griffin, 1993). As such, creativity is highly relevant to contemporary organizations from a variety of industries (Amabile, 1998). In their struggle for competitive differentiation, organizations gradually shift their focus from routine, transactional business processes to processes that rely on knowledge, experience, and creativity (Marjanovic, 2008). Focusing on creativity allows organizations to sustain a source of competitive advantage that can hardly be replicated by competitors (Florida & Goodnight, 2005).

Individual capabilities − such as expertise, imagination, and inspiration − constitute the foundation of creative social interaction (Fischer, Giaccardi, Eden, Sugimoto, & Ye, 2005). The augmentation and improved utilization of individual creativity is, hence, a key to organizational creativity and, consequently, economic performance. Appropriate socio-technical settings can facilitate individual creativity and multiply this potential within a group of creative people (Fischer et al., 2005). Information technology (IT) can support creativity on at least two distinct levels (Greene, 2002): First, it can assist creative individuals in collecting, sharing, exploring, and integrating knowledge in the process of generating creative ideas (e.g., knowledge management systems). Second, it can be directly applied in the process of designing creative products (e.g., tools for computer-aided design).

Understanding knowledge management systems, which are the focus of this paper, requires us to look more closely at the relationship between knowledge and creativity − a topic that has been widely discussed in the literature (e.g., Weisberg, 1999; Woodman et al., 1993). Datta (2007), for example, places creativity into the context of the process of organizational knowledge management and elevates creativity to the central role in an organization's intention to transform knowledge into innovation. Similarly, Hargadon and Sutton (1997) stress the importance of creatively combining existing, but previously unconnected, knowledge from different communities of practice in the course of the innovation process. Notwithstanding the indisputable relationship between knowledge and creativity, there has also been a discourse on whether existent knowledge can inhibit creative problem solving, as it may bias the creative process (Bonnardel & Marmèche, 2005; Weisberg, 1999). In this line of thought, Elam and Mead (1990) assert that software has the ability to both undermine and enhance creativity. They stress the relevance of understanding how software influences creativity and insist on grounding the design of supporting tools in this understanding.

The purpose of this paper is to describe an information systems design theory as a "systematic specification of design knowledge" (Gregor & Jones, 2007, p. 314) to build IT systems that can assist individuals in generating creative ideas through the adequate provision of knowledge. We believe the theory constitutes a valuable contribution to the IS body of knowledge, as it provides both guidance to software developers and avenues for further academic research.

The paper is organized as follows. In the next section, we provide the research background for the present study. We dwell on the role of knowledge in creative work and discuss related studies that address the design of appropriate IT support. Next, we explain the peculiarities of a design theory in IS research, and then describe a design theory for IT systems that support creative work through the provision of knowledge. Subsequently, we outline plans for an empirical evaluation of the proposed design theory. We close with a discussion of limitations and provide some conclusions.

2. Research Background

2.1. Knowledge in Creative Work

Knowledge is a critical factor within the creative process, as it empowers individuals to produce novel insights (Candy & Edmonds, 1997; Woodman et al., 1993). Research on creative problem solving asserts that prior situations often provide a central source of inspiration for new ideas (Bonnardel, 2000): Creativity results from relating working memory to long-term memory (Koestler, 1964); and being creative often means “to put existing ideas together in new combinations” (Amabile, 1998, p. 79), that is, to activate and integrate previous knowledge in novel ways (Wilkenfeld & Ward, 2001). Thus, existing knowledge determines the potential pathways when humans search for a creative solution and is a fundamental prerequisite for creativity (Amabile, 1983; Couger, Higgins, & McIntyre, 1993).

Notwithstanding its indisputable relevance for the creative process, knowledge does not necessarily have a solely positive impact on an individual’s creative capacity (Carlile, 2002). There is evidence that existing knowledge may even compromise creativity, as individuals tend to reproduce what they are used to, or look for concepts that match their usual findings (Bonnardel & Marmèche, 2005). Available knowledge constitutes the “network of possible wanderings” (Newell & Simon, 1972, p. 82) in creative idea generation, and people tend to follow the beaten track. Cheung, Chau, and Au (2008) examine the impact of available knowledge on a person’s creative ability. In a laboratory experiment, they measure how the use of an intranet-based knowledge repository influences the number and quality of creative solutions produced in response to an experimental task. The study suggests that individuals who engage in knowledge reuse perform less creatively in terms of solution quality than those who do not. Cheung et al. (2008) argue that this effect is due to the nature of the applied IT system, which only provides knowledge without considering the peculiarities of knowledge reuse in creative work. Existing knowledge must not restrict the generation of creative ideas by suggesting that the solution to a creative problem constitutes a close copy of this knowledge.

To summarize, creative work includes both the convergent process of identifying relevant, existing things, such as factual knowledge, and the divergent process of putting these together in novel ways (Guilford, 1967; Runco, 2007; Weisberg, 1999). Convergent thinking refers to the mode of human cognition that strives for the deductive generation of a single, concrete, accurate, and effective solution (Guilford, 1967). Divergent thinking, in contrast, requires imagination, provocation, unstructured syntheses, serendipitous discovery, and answers that break with conformity. This mode of cognition focuses on the synthetic generation of multiple disparate answers to a given problem (Amabile, 1998). For “a creative person to produce socially useful products, his or her divergent thinking must come hand in hand with convergent thinking” (Woodman et al., 1993, p. 299).

2.2. IT Support for Creative Work

The above descriptions of convergent and divergent thinking have also been recognized by researchers interested in the design of IT support for creative work. Providing access to both relevant knowledge (i.e., support of convergent thinking) and sources of inspiration (i.e., support of divergent thinking) has always been deemed relevant to the design of creativity support systems (CSS). In his collect-relate-create-donate framework, Shneiderman (2002) lists a set of activities involved in human creative work. Among others, “searching and browsing digital libraries” (p. 118) and “thinking by free associations to make new combinations of ideas” (p. 118) are identified as key tasks that should find appropriate software tool support. Greene (2002) names characteristics such as support for search, retrieval, and classification; engagement with content; and pain-free experimentation, iterative work, and trial and error as key for creativity support tools. Lubart (2005) proposes a classification scheme that distinguishes four categories of human-computer interaction in promoting creativity, where systems of the coach category aim to support the individual cognitive process through the provision of knowledge and sources of inspiration. Candy and Edmonds (1996) conclude that computer support for creative design must enable the designer to flexibly interact with design-relevant knowledge and provide mechanisms that help the designer to “break out of the conventional design space” (p. 88). Similarly, Dominowski and Dallob (1996) argue in favor of a library of practice problems, similar to potential future problems, which can then stimulate creative thinking; and Hewett (2005) calls for the provision of a user-expandable library of reusable objects that can be merged into new creative solutions in a copy-and-paste fashion. Similarly, Eaglestone et al. (2007) identify the reuse and combination of existing elements from multiple applications, the capability for free associations, and the serendipitous generation of solutions as key factors for creative composition environments. While all these research contributions acknowledge the importance of supporting both the convergent and divergent aspects of creative work by means of IT, they do not go beyond a call for action. The authors state goals or requirements at a rather general level; technical means of addressing these are not specified in detail.

Research on actual IT systems (i.e., implementations) for the support of creative work predominantly deals with two different classes of systems: group creativity support systems (GCSS) and individual creativity support systems (ICSS). The former class facilitates remote brainstorming sessions (Ocker, Fjermestad, Hiltz, & Johnson, 1998) or compensates for social group effects such as production blocking, evaluation apprehension, and social loafing (Nijstad & Stroebe, 2006; Nunamaker, Applegate, & Konsynski, 1987; Shepherd, Briggs, Reinig, Yen, & Nunamaker, 1995). ICSS codify various creativity techniques in order to guide an individual user through the idea generation process (Malaga, 2000). The vast majority of IS studies on CSS apply an experimental approach to evaluate the impact of a given implementation on the creative performance of individuals or groups (Seidel, Müller-Wienbergen, & Becker, 2010). Masseti (1996), for instance, conducts a laboratory experiment with two ICSS to measure their influence on the number and novelty of ideas generated by individuals. Elam and Mead (1990) empirically test two hypotheses that relate the use of an ICSS to the number of steps taken in a creative decision process and the creativity level of the generated responses. Easton, George, Nunamaker, and Pendergast (1990) apply a similar setting for evaluating the effect of two different GCSS, and Shepherd et al. (1995) measure the compensating effect of GCSS on different social group effects.

There is little research that provides an in-depth discussion of the design of CSS. Typically, these studies focus on the divergent aspect of idea generation. The proposed system designs cater to the stimulation of creative thinking, but neglect the issue of how to provide access to relevant knowledge. Drawing from the metaphor of a Rubik's Cube, Huang, Wang, and Chang (2007), for example, design a game-like collaborative brainstorming tool that offers features to stimulate creativity by shifting perspectives on a given creative problem. MacCrimmon and Wagner (1991-1992, 1994) introduce the GENI (GENerating Ideas) system that aims to support problem structuring, idea generation, and idea evaluation. In order to stimulate idea generation, the system's key component implements a mechanism that helps users making connections between different aspects of a problem as well as different aspects of emergin ideas. Young (1987) proposes a relational database schema and an algebra for the automatic generation of metaphors, which constitute a recognized source of creative inspiration.

To summarize, we identify a lack of research on how to design IT systems that support both convergent and divergent thinking in creative work. Existing research either postulates rather generic design requirements lacking any detailed specification on how to address these requirements, or it focuses on a specific IT system that only supports divergent thinking. Due to the central role of both modes of creative cognition, and their intimate relationship in solving creative problems, we contend that there is a need for a detailed design specification considering both levers to support creativity. Instead of developing a single implementation, this study aims to define a design that generalizes to an entire class of systems. Against this background, in the following sections, we will present an IS design theory for systems that support convergent and divergent thinking in creative work.

3. Design Theory in Information Systems Research

The development of design knowledge, for instance, in the form of reusable design patterns, principles, or guidelines, is of high importance to both IS research and practice (Kuechler & Vaishnavi, 2008; Winter, 2008) and has gained increasing recognition over the last several years (Baskerville, 2008; Lee & Nickerson, 2010). At its core, design science is concerned with the systematic creation of new knowledge about a problem and its solution through building and evaluating innovative artifacts (Hevner & Chatterjee, 2010). Consequently, the primary goal of design science is the utility of the resultant artifacts (Hevner & Chatterjee, 2010). While it is widely acknowledged that design science should be informed by existing theories (Baskerville, 2008; Kuechler & Vaishnavi, 2008; Walls, Widmeyer, & El Sawy, 1992), Gregor (2002, 2006) affirms that knowledge on the design of an IT artifact also exhibits the characteristics of a theory (Type V theories, i.e., theories for design and action). Gregor and Jones (2007) build upon, and expand, the seminal work of Walls et al. (1992) and state that "an IS design theory shows the principles inherent in the design of an IS artifact that accomplishes some end, based on knowledge of both IT and human behaviour" (p. 322). In this line of thought, Kuechler and Vaishnavi (2008) subsume that a majority of studies that discuss theory in the context of design science research understand theory as "a significant, perhaps the most significant, output" (p. 490) of design-oriented IS research.

Gregor and Jones (2007) further explicate structural components that are needed to specify and communicate a design theory: (1) the purpose and scope, which specify the type of artifact to which the theory applies as well as its boundaries, (2) the constructs that are of interest to the theory, (3) the principles of form and function, which constitute an abstract blueprint of the IT artifact, (4) an artifact's mutability, that is, the anticipated changes to the artifact encompassed by the theory, (5) a set of testable propositions about the type of system to be constructed, and (6) the underlying knowledge that gives an explanation for the design. The latter component comprises the justificatory knowledge that substantiates the proclaimed design decisions (Gregor & Jones, 2007). This knowledge constitutes the kernel theories of a design theory and can originate from both the natural and the social sciences (Simon, 1996). Moreover, supplementary design theories, evidence-based justification (van Aken, 2004), or practitioner-in-use theories (Sarker & Lee, 2002) also constitute valid theoretical grounding for the development of design theories (Gregor & Jones, 2007). In addition to the six mandatory components, Gregor and Jones (2007) identify the formulation of (7) implementation principles as well as the provision of (8) a physical instantiation as being optional to the specification of an IS design theory. The latter serves the purposes of theory representation and exposition and is likely to enhance the theory's credibility by demonstrating a design's feasibility (Gregor & Jones, 2007).

In this article, we present all eight components of an IS design theory. The next section defines the design's purpose and scope. Then we derive a set of design requirements from justificatory knowledge that give guidance to the subsequent specification of our design. The following section exhibits the theory's core constructs as well as its underlying principles of form and function. We then state implementation principles concerned with the process of setting up and maintaining the proposed class of systems. Subsequently, we discuss a prototypical instantiation by applying an illustrative example and, thus, exemplify the theory's purpose and functional principles and expose its feasibility. Moreover, we discuss the theory's mutability aspect and develop a set of testable hypotheses that are meant to inform the future evaluation of the proposed design theory.

4. A Design Theory for Systems that Support Convergent and Divergent Thinking

4.1. Purpose and Scope

The purpose of the proposed design theory is to give explicit prescriptions about how to develop IT systems that support creative work through knowledge provision. As outlined above, knowledge provision in creative problem solving comprises both the convergent process of identifying relevant existing knowledge and the divergent process of putting identified bits of knowledge together in novel and purposeful ways. IT systems are capable of supporting both cognitive processes (Avital & Te'eni, 2009; Massetti, 1996). However, to the best of our knowledge, there is no study that has formalized design knowledge on systems that support both cognitive processes in an integrated manner. To close this gap, the goal of the proposed design theory is to explicitly formulate prescriptions for a class of IT systems that simultaneously support convergent and divergent thinking in creative work.

While the focus of the proposed design is to support individuals, we expect that the formulated prescriptive statements will also apply for group settings. Moreover, the proposed class of IT systems is deemed appropriate to support a wide range of creative tasks. What these tasks have in common is the reuse of digital, explicit knowledge. That is, knowledge may either become part of a novel product or it may function as a stimulus for creative people to help them come up with creative ideas. Such systems can, for example, support a product designer by providing a library of existing products, components, and materials in order to gain inspiration for a new design; support a visual effects producer in composing a scene by offering a repository of graphics, animations, and sound effects; support a location scout in the search for a movie location by providing a database of digital imagery about diverse locations; or even support an artist in finding inspiration for a new piece of artwork by presenting a catalogue of paintings, graphics, and photographs.

4.2. Justificatory Knowledge

Creativity typically emerges from discovering new associations between previously disparate things that become activated together within the creative problem solving process (Koestler, 1964; Mednick, 1962). The discovery of similarities between previously disparate concepts is closely related to the process of analogical thinking (Couger et al., 1993). Various studies have proven the central role of analogies in producing creative ideas (Candy & Edmonds, 1996; Dominowski & Dallob, 1996; Finke, Ward, & Smith, 1992; Hesse, 1966; Holland, Holyoak, Nisbett, & Thagard, 1986; Thagard, 1988), confirming analogical thinking as "one of the hallmarks of creative problem solving" (Thomas, Lee, & Danis, 2002, p. 113). Thinking by analogy means "trying to reason and learn about a new situation (the *target* analog) by relating it to a more familiar situation (the *source* analog) that can be viewed as structurally parallel" (Holyoak & Thagard, 1997, p. 35). In creative work, existing knowledge can be regarded as source analogs that help to solve a creative problem at hand (target analog) (Holyoak & Thagard, 1996; Minsky, 1986). Thus, in the following two subsections we propose different facets of a design that, on the one hand, supports access to existing knowledge (supporting convergent thinking) and, on the other hand, stimulates mental associations (supporting divergent thinking). Based on this justificatory knowledge, we derive a set of design requirements.

4.2.1. Supporting Convergent Thinking in Creative Work

The convergent process in the context of creative work differs from the usual goal of information retrieval: that is, achieving an accurate match between a query and retrieved items (Ford, 1999). When acting creatively, people do not seek "known" knowledge as they do in a well-defined search (retrieval by specification); rather, they search for something potentially relevant (retrieval by recognition) through a process called scanning or browsing (Belkin, Marchetti, & Cool, 1993).

Prior research on human cognition suggests that hierarchical classification schemes can provide a suitable means for supporting knowledge retrieval in situations characterized by high uncertainty, such as creative work: Virtually all knowledge representation systems − including the human memory − are based on some sort of hierarchy (Miller, 1990); they consist of tree-like structures for categorizing classes of things in the world, formally known as taxonomic hierarchies (Brachman, 1983; Touretzky, 1986). In *network models of human semantic memory*, such as Quillian's (1967) *word concepts* theory, inheritance relationships between different concepts form the backbone of a hierarchical knowledge representation system in which high-level nodes represent generic, large categories, and low-level nodes represent specific, small categories (compare also Collins & Quillian, 1969; Quillian, 1969). The inheritance or generalization/specification relations between the concepts of such a hierarchy constitute intuitive orientation and abstraction mechanisms that facilitate top-down search strategies (Furnas & Zacks, 1994). Hierarchical classification structures are, thus, deemed appropriate to lead individuals along the stepwise refinement process of their indefinite information needs in creative work. Hierarchical classification schemes also favor the process of abstraction, which has a central role in creative problem solving (Ford, 1999). As creative insight stems from the identification of an integrating theme of otherwise discrete entities, the similarities among those entities typically rest on a high level of abstraction (Ford, 2004). Classification hierarchies pertain to specific trails of abstraction and, thus, exhibit different potential levels of similarity that can inspire the identification of "creative" integration patterns. Correspondingly,

> *Design Requirement C.1 (Organize available knowledge hierarchically): In creative problem solving situations, provide a hierarchical categorization of knowledge so as to support the stepwise refinement of indefinite information needs and to exhibit abstract similarities between seemingly disparate entities.*

The nature of creative work demands multiple perspectives of knowledge organization. First, neither the final outcome of creative work nor the process of its generation is known in advance (Getzels, 1964). Second, creativity is typically fostered by the collaboration of people with different backgrounds and views on the creative task at hand (Amabile, 1998; Mamykina, Candy, & Edmonds, 2002). Thus, we contend that supporting IT systems are required to fit for a variety of creative problem solving situations and appeal to different creative problem solvers. The existing knowledge considered relevant by a person as well as how this knowledge is accessed depend on both a person's worldview and the specifics of the task at hand (Pask, 1976; Polanyi, 1975). In the context of creative problem solving, this calls for multiple classification structures that offer diverse perspectives on existing knowledge (Furnas & Zacks, 1994; Markus, Majchrzak, & Gasser, 2002). These can categorize classes of things along orthogonal thematic dimensions (e.g., place, time, function, structure) or can be built upon different semantic relations between classes (e.g., subclass-of, instance-of, part-of (Storey, 1993)) − a key concept also inherent in most network models of human semantic memory. Thus, multiple means of knowledge access help by bridging a user's mental model, the information needs of a given creative problem, and the way both are supported by an IT system (Ingwersen, 1992; Norman, 1984, 1986). Correspondingly,

> *Design Requirement C.2 (Provide diverse perspectives on existing knowledge): In creative problem solving situations, provide multiple classification structures reflecting diverse perspectives on available knowledge so as to support various creative individuals and various creative tasks.*

What holds for the means of knowledge access also applies to the knowledge itself: to be appropriate in various creative problem solving situations as well as for various creative problem solvers, it has to be diverse. The exploration of knowledge collections, however, becomes increasingly difficult as their volume grows (Shneiderman, 1996). *Information processing theory* suggests that humans have limited cognitive capacity to process information (Miller, 1956). Accordingly, Huang et al. (2007) argue that while a system for creativity support should cater to the proper presentation of relevant knowledge, it should also avoid overloading users with "information noise" (p. 31). Users should have ample ability to quickly eliminate unwanted items from the scene (Shneiderman, 1996). Moreover, the means of querying and filtering have to fit with the explorative and experimental nature of creative problem solving (Greene, 2002; Terry & Mynatt, 2002). Shneiderman (2007), for example, advances the application of what he calls dynamic queries (Shneiderman, 1994) as a means of knowledge retrieval that allows users to interactively, and even playfully, explore the contents of a knowledge repository using graphical controls. A digital knowledge environment that is meant to support creative work has, thus, to cater to the immediate, incremental, and reversible exploration of accessible knowledge (Shneiderman, 2007). Correspondingly,

> *Design Requirement C.3 (Enable dynamic filtering of the knowledge base): In creative problem solving situations, provide dynamic means of knowledge querying and filtering so as to avoid information overload while exploring a knowledge repository.*

In the next section, we shift the focus from the convergent retrieval of external knowledge items to the internal, mental process of divergent thinking. Hence, in the following section, the term knowledge does not refer to digital pieces of information, but to knowledge residing in the human memory.

4.2.2. Supporting Divergent Thinking in Creative Work

Creativity often originates from the sudden recognition of a similarity between disparate entities, experienced as a perceptual flip that changes one's interpretation of a given situation (Ford, 1999). Various researchers from different disciplines argue for the provision of external stimuli to initiate these serendipitous flashes of insight (Bonnardel, 2000; Dugosh, Paulus, Roland, & Yang, 2000; Santanen, Briggs, & de Vreede, 2004). Stimuli can exhibit new potential analogies that otherwise would not be taken into consideration − a principle that can be found in various approaches to idea generation. The brainstorming technique (Osborn, 1963), for example, utilizes the ideas of others as stimuli for the idea generation process. Becoming conscious of the existence of different perceptions of a given task helps scrutinizing one's personal strategy for striving for a creative solution (Shekerjian, 1990). The *search for ideas in associative memory* (SIAM) model, proposed by Nijstad and Stroebe (2006), explains the underlying mechanisms of this effect. The model assumes that knowledge activation is cue dependent. A problem definition as well as previously activated knowledge is applied to reveal localized sets of knowledge from long-term memory. These knowledge sets possess different features that can then be applied for idea generation. New ideas add to the set of search cues and, thus, keep alive the iterative process of memory retrieval and idea generation (Nijstad & Stroebe, 2006). External stimuli constitute search cues that are independent from this process. As such, they can enhance an individual's creative performance if they reflect a category of ideas outside the reinforcing internal idea generation loop (Diehl, Munkes, & Ziegler, 2002). Correspondingly, *Design Requirement D.1 (Provide external stimuli): In creative problem solving situations, provide external stimuli to evoke ideas that lie outside the trails of habitual idea generation.*

Two different types of stimuli can be distinguished. Stimuli can either exhibit new categories of ideas, causing a high diversity of generated ideas, or they can foster the creation of ideas within the same category (Nijstad & Stroebe, 2006). In an empirical study Bonnardel and Marmèche (2005) examine what sources of inspiration designers − both novice and experts − consider when they solve a specific design problem. The authors distinguish between two types of analogies that can facilitate creative thinking: intra-domain and inter-domain analogies. Stimuli that invoke an intra-domain analogy lie in the same semantic domain as the object being designed. The stimuli share many characteristics with the target object. Inter-domain analogies, in contrast, are provoked from stimuli that do not belong to the same category as the target object. These analogies relate to features or properties of the target object that are not prototypical of its category; they help to generate ideas from different categories. In the Bonnardel and Marmèche (2005) study, the participants had to design a seat for a café. Intra-domain analogies arose from objects belonging to the "seat" category such as an office seat or a camping seat. Inter-domain analogies resulted from making reference to the warmth or softness of a seat, for example, by presenting the picture of a bird's nest.

Both types of stimuli are relevant to creative problem solving. Inter-domain analogies exhibit the greatest creative potential, as they force a problem solver to take a point of view dissimilar to the obvious solution space (Bonnardel, 2000; Nijstad & Stroebe, 2006). Santanen et al. (2004) use the *cognitive network model* to explain how and why the combination of more dissimilar entities bears a higher potential for forming creative solutions than that of homogeneous entities. They argue that the "associative distance" (p. 189) between knowledge sets activated together is directly related to the likelihood of revealing a new association and, in turn, generating a creative idea. Yet, different types of creative problem solvers warrant a demand for both types of stimuli. In the course of the Bonnardel and Marmèche (2005) study, novice designers, unlike expert designers, assigned higher scores of usefulness to intra-domain stimuli than to inter-domain stimuli and also came up with significantly more ideas in response to the former type of stimulus. Providing another reason for the relevance of both types of stimuli, Nagasundaram and Bostrom (1994) identify two distinct types of creative problems that demand two different types of creative solutions. Paradigm-preserving ideas reflect an evolution of an existing solution (Kirton, 1976), whereas paradigm-modifying ideas redefine a given problem or its elements (Garfield, Taylor, Dennis, & Satzinger, 2001). The latter are revolutionary and arise from stimuli that expose a truly novel perspective, that is, they typically originate from a different domain. The former, in contrast, are ideally supported by stimuli that stem from the same domain and, thus, preserve the paradigm (Satzinger, Garfield, & Nagasundaram, 1999). Correspondingly,

Design Requirement D.2 (Provide different levels of stimuli): In creative problem solving situations, provide both intra- and inter-domain stimuli so as to allow for the induction of both paradigm-preserving and paradigm-modifying ideas and to serve individual preferences in idea generation.

From prior research on human cognition, we know that the effect of stimuli also depends on their appearance: The *dual coding theory* (Paivio & Lambert, 1981) suggests that human memory and cognition are served by two separate symbolic systems that are interconnected but also capable of functioning independently. One system handles verbal information, and the other processes non-verbal information. The two are, however, intimately connected, and search cues to the one system can evoke knowledge sets in the other system. A picture, for example, may evoke verbal associations, while a specific word may bring images into someone's mind (Malaga, 2000). Prior research has shown that the simultaneous use of lexical and pictorial stimuli is conducive to one's ability to recall knowledge from memory (Paivio, 1983). Furthermore, the separation between the systems implies that naming a concept and visualizing the same can stimulate different knowledge sets and, thus, provoke different creative ideas. Besides, individuals have individual abilities in the use of verbal and visual problem solving strategies (Malaga, 2000). Correspondingly, *Design Requirement D.3 (Stimulate both symbolic systems of human cognition): In creative problem solving situations, provide both verbal and non-verbal stimuli addressing both symbolic systems of human cognition so as to cater to different creative styles and provoke the mutual reinforcement of both systems.*

4.3. Constructs and Principles of Form and Function

In the following, we present "an abstract 'blueprint' or architecture for the construction of an IS artifact" (Gregor & Jones, 2007, p. 326). It translates the design requirements derived from the literature and the kernel theories into basic constructs and principles underlying a class of IT systems. Constructs represent the most basic units of a design theory. In Gregor and Jones' (2007) example of Codd's (1970) relational database model, *tables* and *n-ary relations* are quoted as typical constructs of a design theory. A corresponding principle of form and function is that *the order of rows in tables is arbitrary and irrelevant*. In the following, we will first present the basic constructs of the proposed design theory and subsequently elaborate on the corresponding principles of form and function (cf. Appendix for a formal specification of these elements).

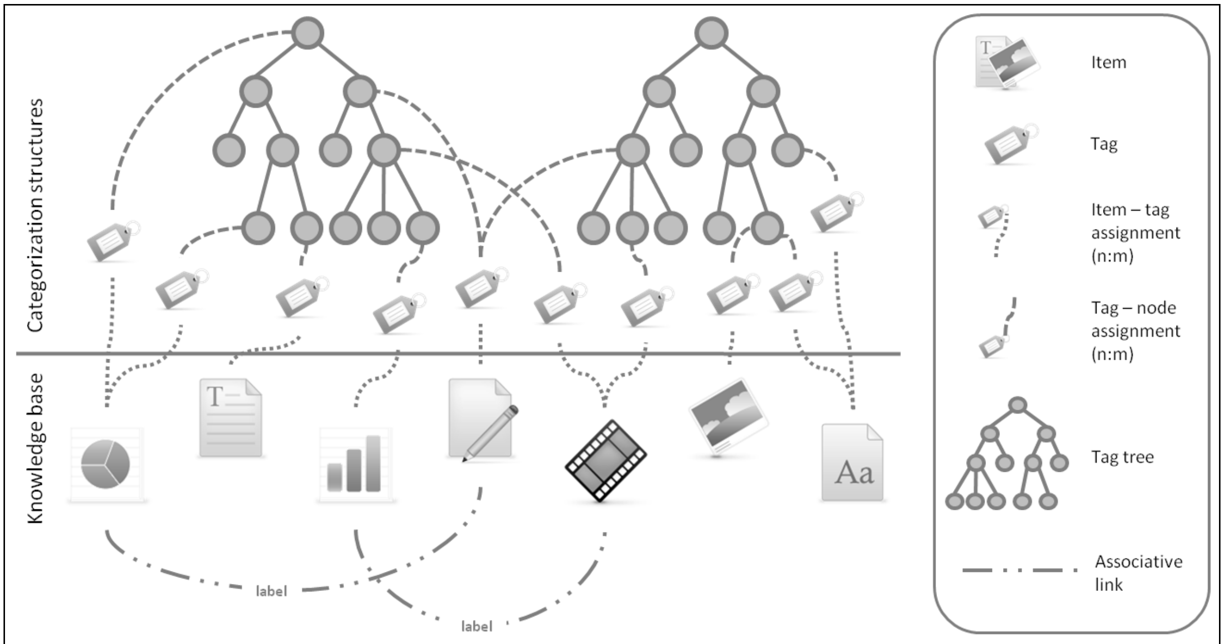

Figure 1. Constructs of the Design Theory

4.3.1. Design Theory Constructs

Digital documents of diverse formats (e.g., text, image, music, and video files) represent the explicit, codified knowledge underlying the proposed system design (cf. Fig. 1). For organization and retrieval purposes, these knowledge *items* can be annotated with multiple *tags*, that is, short, textual classifiers. The tags are assigned to *nodes* of hierarchical categorization structures, resulting in what we call *tag trees*. Users are able to modify and extend tags and tag trees. Hence, the proposed approach represents a meet-in-the-middle stance between static, hierarchical facetted categorization systems (Hearst, 2006) and user-generated, flat tag clouds (e.g., Flickr). In addition to the hierarchical categorization through tag trees, following the notion of free association (Kris, 1996), the design proposal includes free *associative links* between knowledge items. Users can arbitrarily create and label these links on the fly without any categorization scheme in mind (DeRose, 1989).

4.3.2. Design Principles for Convergent Thinking

In order to support the convergent aspect of creative work, the proposed design theory comprises different principles to retrieve stored knowledge items.

Tag trees constitute the primary means for accessing knowledge items (cf. Design Requirement C.1). Users can drill down into a tag tree and scan through the items that are assigned to the corresponding tags (similar to online analytical processing in data warehouses). Furthermore, it is possible to navigate in multiple tag trees simultaneously in order to quickly obtain an understanding of the structure and contents of the knowledge base. The different tag trees provide different perspectives of the knowledge items and offer a variety of paths for retrieving eligible knowledge (cf. Design Requirement C.2).

In addition, leveraging the hierarchal tag trees, the proposed system design provides several mechanisms for dynamically querying the items contained in the knowledge base (cf. Design Requirement C.3). A node filter restricts the shown items to those items that are assigned to a given tag in a given tag tree. A branch filter restricts the set of displayed items to the subset of items that are assigned to a specific tag in a tag tree and all subordinated nodes. Finally, a free text filter allows restricting the set of displayed items to a subset of items that contain a given text string, either within the document itself or in its metadata. That is, the free text filter acts like a traditional keyword search. It is possible to combine several instances of tag, branch, and free text filters in order to flexibly restrict the displayed knowledge items to a set of items relevant to a given creative task.

4.3.3. Design Principles for Divergent Thinking

Aside from facilitating the convergent process of knowledge retrieval, the proposed system design also aims at facilitating the divergent process of creative thinking by providing different sources of stimulation (cf. Design Requirement D.1).

Tag trees, as such, provide a source of intra-domain stimuli (cf. Design Requirement D.2). As every tree represents a stepwise categorization of the assigned items in relation to a specific perspective, drilling down into a tag tree exposes a user to various available options from a focused domain. All nodes and branches that a user does not initially intend to visit may exhibit alternatives that have not been considered before and, thus, come with the potential of stimulating the discovery of a novel solution.

Another way to find potential intra-domain stimuli is to analyze the actual contents of knowledge items. For a given knowledge item, a user can request recommendations of items that are similar in content. In order to determine similarity, important descriptive features of a selected item are extracted using information extraction techniques and then applied to filter the internal knowledge base for similar items (Manning, Raghavan, & Schütze, 2008).

The plurality of tag trees constitutes a source of inter-domain stimuli (cf. Design Requirement D.2). Every tag tree represents a different classification scheme. Tag trees can, for instance, refer to functional (use of an object), structural (physical composition of an object), affective (sensations aroused by an object), or aesthetic (sensitized beauty of an object) properties of the stored items (Bonnardel & Marmèche, 2005). Hence, providing alternative tag trees and exhibiting associations between tag trees can provoke a perspective shift for the user. Pointing to a perspective that has not led a user's knowledge retrieval process so far can, thus, allow for the development of new ideas from a different domain.

In particular, we propose the following features to generate inter-domain stimuli. The general idea is to exhibit existing and prospective associations within the knowledge base:

- *Items can serve as junctures between tag trees, as an item is typically classified by multiple tags from different trees. Hence, if the user is focusing on a specific knowledge item, the system displays all tags assigned to the item. As tags describe the different facets and properties of an item, this may help to discover new associations that can lead to rather distant, but potentially creative solutions.*

- *Tags can constitute hubs in the navigation structure of the knowledge base, as they can occur in more than one tag tree (cf. Fig. 1). The system informs the user when a particular tag is present in more than one tag tree and offers a traversal to one of those trees. This has the potential to initiate a shift of the user's perspective on the creative* *problem at hand and, subsequently, may lead to the generation of ideas that might stem from a totally different domain.*

- *In order to generate inter-domain stimulation, item-tag assignments can be analyzed. We assume that two tags are somehow related to each other, if they share a large set of assigned items. Hence, the system points out latent relationships between tags from different tag trees based on a calculation of their relative, pairwise item intersection. This can reveal prospective associations between tags, even if there is no direct physical link between them.*

- *The user-generated associative links between knowledge items represent another potential source of inter-domain stimulation. The system allows users to freely create and label arbitrary relationships between knowledge items. These links are not only visible to the users who originally created them, but to all users of the system. Similar to group brainstorming, the idea behind this social linking mechanism is to utilize associations created by others as fresh input for one's own creative process.*

Finally, our design considers both symbolic systems of human cognition, that is, verbal and non-verbal cognition (cf. Design Requirement D.3). The proposed system can store digital items of various formats that serve as verbal and non-verbal stimuli. In addition, the system integrates external multimedia content from social networks such as Flickr, YouTube, and Twitter. This data represents rich multimedia content that does not stem from the original users of the system and, hence, has the potential to provide new inspiration, even for users who work with the system on a regular basis. For pragmatic reasons, the external content is not subject to the system's categorization structures (i.e., tags, tag trees). Rather, the content-based filtering techniques that are used to retrieve similar internal knowledge items are also applied to filter the stream of content from the tapped social networks. Hence, focusing on a particular item, the user can request similar items not only from the internal knowledge base, but also from the connected external data sources.

Table 1 summarizes the design requirements derived from theory and literature and pinpoints how each of these is addressed by the proposed constructs and principles of form and function.

Table 1. Mapping of Design Requirements to Constructs and Principles of Form and Function

Design requirement	Constructs and principles of form and function
C.1: Organize available knowledge hierarchically	Knowledge items can be categorized by multiple tags, which are organized in hierarchical tag trees.
C.2: Provide diverse perspectives on existing knowledge	Different tag trees provide different perspectives of the knowledge items.
C.3: Enable dynamic filtering of the knowledge base	Different types of graphical filters can be combined to interactively restrict the set of displayed knowledge items.
D.1: Provide external stimuli	Stimuli originate from the knowledge items, tags, tag trees, content-based item recommendations, algorithms mining associations between tag trees, associative links between items, and tapped external data sources.
D.2: Provide different levels of stimuli	The stepwise categorization of items within a tag tree and the possibility to retrieve items with similar content provide intra-domain stimuli. The plurality of tag trees, the algorithms mining associations between tag trees, and the associative links between knowledge items produce inter-domain stimuli.
D.3: Stimulate both symbolic systems of human cognition	The internal knowledge base contains both verbal and non-verbal knowledge items. In addition, multimedia content from tapped social networks can be requested.

4.4. Principles of Implementation

In the following, we will discuss issues that are concerned with "the means by which the design is brought into being – a process involving agents and actions" (Gregor & Jones, 2007, p. 328). We will concentrate on the issues of bootstrapping and continuously maintaining a concrete instantiation of the proposed class of IT systems. The main implementation problem is to ensure that the proposed system hosts a critical mass of relevant content. Only if the system's knowledge base and categorization structures are both broad and deep enough to provide the necessary level of associative distance required for forming creative solutions does it have the potential to yield positive effects on an individual's creative performance (Bonnardel, 2000; Nijstad & Stroebe, 2006; Santanen, Briggs, & de Vreede, 2000).

We suggest two implementation principles. First, the system shall be implemented and maintained in a way that makes use of existing content, both from internal sources (e.g., archives of past creative problems and solutions) and external sources (e.g., online repositories of creative commons content), thus allowing users to explore a rich knowledge base from the beginning (Implementation Principle I.1). Second, the system shall be implemented and maintained in a way that enables the hosting of user-generated content, thus ensuring that its knowledge base does not outdate and become irrelevant over time (Implementation Principle I.2). Table 2 provides an overview. Note that we do not claim exhaustiveness.

Table 2. Implementation Principles

Implementation principle	Description
I.1: Leverage existing internal and external data sources	Integrating existing content from internal and external data sources helps to ensure that the system provides a critical mass of content required to stimulate the forming of creative solutions.
I.2: Motivate user-generated content	Allowing user-generated content and encouraging users to act as contributors and collaborators helps to steadily assure the relevance and timeliness of the knowledge base.

The technical means to allow the above implementation principles are already implemented in the expository instantiation presented in the next section; however, a system that lives through user-generated content calls for users who are not solely readers or consumers, but rather act as contributors or collaborators, adding new knowledge to the system (Preece & Shneiderman, 2009). Besides good usability design, this entails considering "sociability" factors such as norms for appropriate contributions, support for gradual participation, recognition for high quality and quantity of contributions, or the chance to build a reputation within the user community (Preece & Shneiderman, 2009).

4.5. Expository Instantiation

In the following, we present a prototypical instantiation of the proposed design architecture "for the purpose of theory representation and exposition" (Gregor & Jones, 2007, p. 329). We chose the creative task of location scouting as an example case, as it requires high levels of creativity from the involved people. Location scouts are vital members of the design team for film, television, music video, and advertising productions (LMGA, 2010). Their primary job is to find locations that best reflect the aesthetic goals of a production. The creative dimension of their work assumes an advanced level of visual and aesthetic skills combined with knowledge related to specific locations and neighborhoods as well as urban developments, architectural styles, and eras. Most location scouts maintain databases of spectacular or interesting locations. These databases contain a rich set of location-related information such as photographs and videos, lighting conditions, map data, building layouts, or lists of local facilities. Location scouts apply these pieces of information to either identify a location among the stored objects that matches a scene's requirements or to get inspired about what a possible location may offer in order to appropriately transport a scene's main idea.

Figure 2 shows a screenshot of the prototypical instantiation that was populated to support the creative task of location scouting. The system's database stores more than 2,000 text documents, images, and video files documenting approximately 500 locations in and around London. These items are categorized from eight different perspectives − area, period, function, structure, style, development, facilities, and content type − that are represented by corresponding tag trees (cf. upper part of the screen in Figure 2).

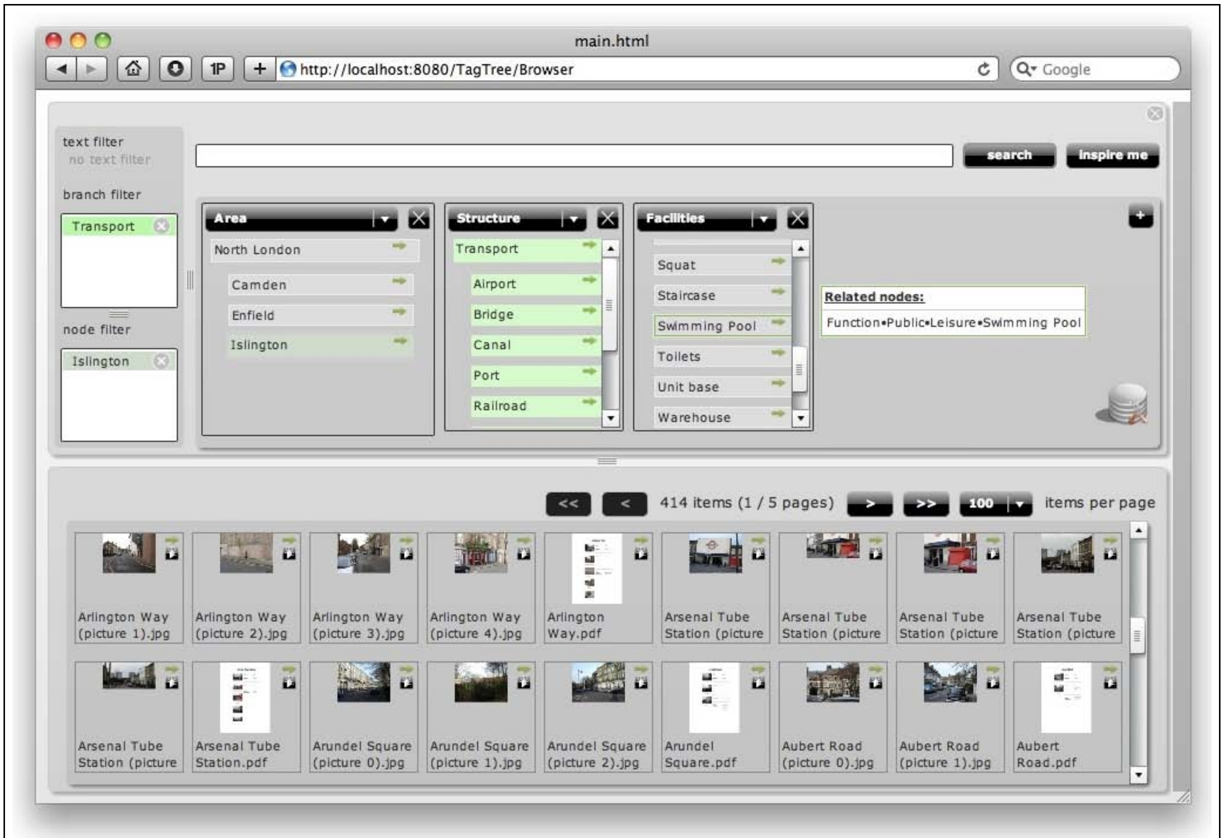

Figure 2. Screenshot of Prototype – Browsing Window

Using the system typically commences by choosing a start perspective and drilling into the corresponding tag tree. When opening the "Area" tag tree, for example, different areas in and around London are displayed. When a user selects one of these areas, for instance "North London," the boroughs of this area (Camden, Enfield, Islington, etc.) are shown at the next navigation level. By dragging "Islington" onto the node filter (cf. left upper part of the screen in Figure 2), the displayed items (cf. lower part of the screen in Figure 2) can be restricted to information related to locations in this very borough. In order to further refine the result set, multiple nodes from different tag trees can be applied for content filtering. For example, a user can open the "Structure" tag tree and browse to the "Transport" tag. Adding a corresponding branch filter limits the result set to transport-related sites (e.g., streets, bridges, railroads, subways, train stations, etc.) in "Islington" (cf. Figure 2).

While a user is browsing a tag tree, the system presents for each node the sub and sibling nodes along the chosen navigation path. It thus directs the user's attention to alternatives that she may not have considered before. When opening the "Transport" node, for example, sub-nodes are presented ranging from "Airport" to "Canal" and "Station" to "Tunnel." For each node, the system can suggest similar nodes from different tag trees that either share the same tag or possess a large item intersection. When searching for a location providing a "Swimming Pool," for example, the location scout may navigate along the "Facilities/Swimming Pool" path (cf. Figure 2). The system points out that the tag "Swimming Pool" is also present in the "Function/Public/Leisure" sub-tree. This may make her contemplate whether there are other public leisure facilities that are of interest to her current project (e.g., gyms, sports grounds). In addition, the system suggests having a look at the “Blue” tag in the “Style” tree, because the tags “Swimming Pool” and “Blue” exhibit a large item intersection. Disclosing this association might induce the user to break out of her current solution space and think about radically new locations that are associated with the color blue (e.g., ocean, sky, FC Chelsea).

Finally, when the user selects a specific item, all assigned tags are displayed. A location description of the “Arsenal tube station,” for instance, is not only reachable via the “Area” or “Structure” tag trees, but also via the “Facilities/Café” path. This may stimulate a traversal to a different tag tree going along with a perspective shift. In addition, focusing on a single item, the location scout can request similar items from the internal database as well as tapped external sources (cf. Figure 3). Requesting inspiration for the item “Arsenal tube station,” for example, produces various pictures of this location as well as text documents describing other locations like the “Archway Tube Station,” “Stratford Bus Station,” or a “BP gas station.” From YouTube, videos of a flash mob at “Grand Central Station” in New York, the David Bowie video clip “Station to Station,” and a video of “Arsenal London” football fans are retrieved. Flickr offers various aesthetic photographs of train and subway stations, and Twitter reveals that many people are waiting bored at train stations or are listening to mixed radio stations.

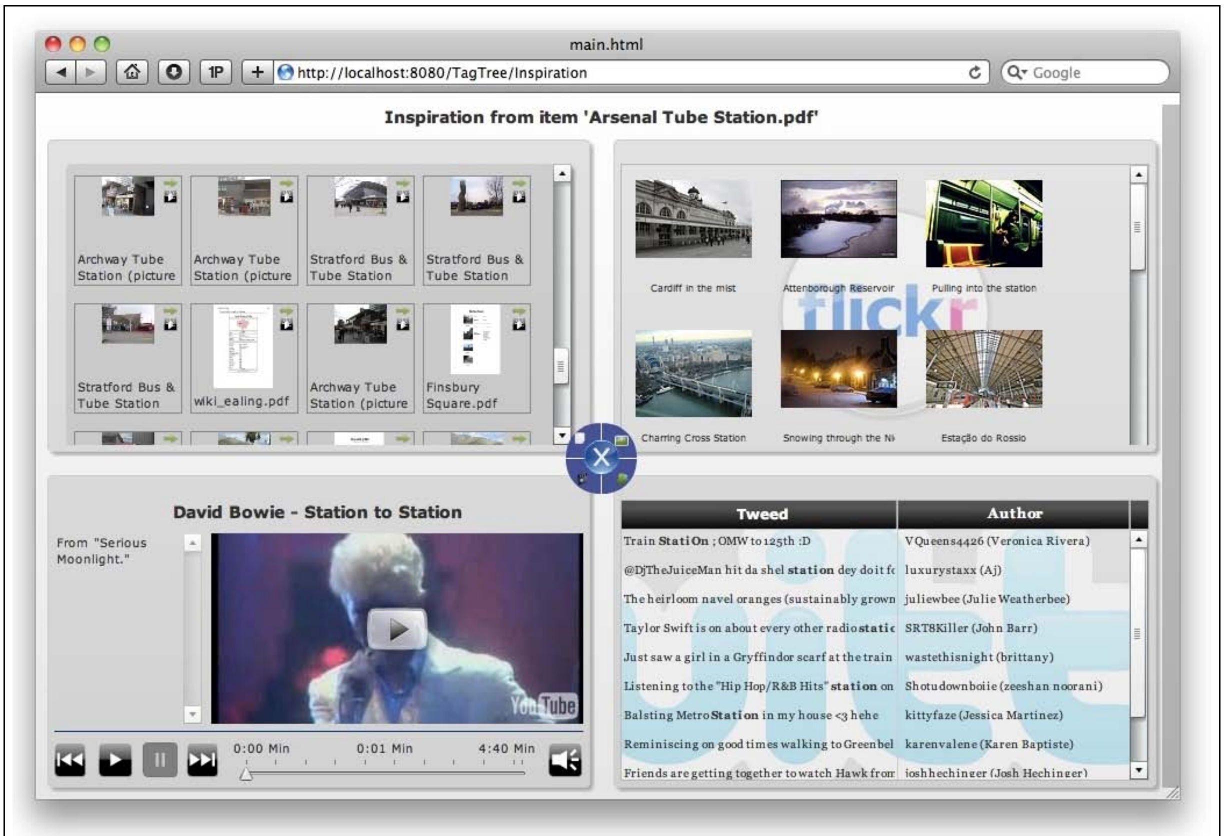

Figure 3. Screenshot of Prototype – Item Inspiration Window

4.6. Artifact Mutability

While the proposed design theory provides a general blueprint of a system design, the appearance of a corresponding concrete IT artifact is dependent on the context in which it will be instantiated. Especially, the instantiation of the theory’s core constructs (i.e., knowledge items, tags, and tag trees) is highly dependent on the socio-economic background of the applied system. Tags and tag trees for finding a suitable film location, for example, will differ from those that are useful for new product development. Likewise, different application settings might require different types of knowledge items (other file formats) or different external data sources (e.g., domain-specific databases). Moreover, even in a given context, the system instantiation will certainly evolve over time. When the system’s knowledge base is populated with new items, new tags and tag trees are needed for classification. Similarly, the user base or the type of creative problems the system is meant to serve may change over time and might require additional items and an extension of the existing categorization structures.

4.7. Testable Hypotheses

As a preparation for design theory testing, Gregor and Jones (2007) argue for testable propositions or hypotheses about the system to be constructed. Therefore, in the following, we present six hypotheses that represent claimed "truth statements about the design theory" (Gregor & Jones, 2007, p. 322) presented here.

As to the dependent variables, empirical studies on creativity support agree upon measuring the quantity of ideas generated by an individual as an indicator for creative performance (for an overview of studies, see MacCrimmon & Wagner, 1994). Additionally, it has been asserted that, in order to assess creative performance, one should also measure whether a treatment leads to improved quality of the creative ideas generated, that is, their novelty and value (Malaga, 2000; Massetti, 1996).

As we have outlined earlier in this paper (cf. Research Background), the importance of leveraging both convergent and divergent thinking in creative problem solving has been recognized by researchers from the field of human cognition (e.g., Guilford 1967; Woodman et al., 1993; Weisberg, 1999) and researchers interested in the design of appropriate IT support (e.g., Candy & Edmonds, 1996; Shneiderman, 2002; Hewett, 2005). Consequently, we expect that using IT that supports both convergent and divergent thinking will result in higher creative performance in terms of quantity and quality of ideas than using IT that only supports one of the two basic modes of cognition. (Surprisingly, prior empirical evaluations of concrete CSS focused almost exclusively on the role of divergent thinking in creative problem solving; see e.g., MacCrimmon and Wagner, 1994; Massetti, 1996; Malaga, 2000.) That is, the independent variable is the software support of the creative process. Correspondingly, we hypothesize that:

> ***H1a****: The use of systems that support both convergent and divergent thinking will result in a greater number of ideas being produced for a given creative task than the use of systems that support only divergent thinking.*

> ***H1b****: The use of systems that support both convergent and divergent thinking will result in more novel and purposeful (i.e., creative) ideas being produced for a given creative task than the use of systems that support only divergent thinking.*

And analogously:

> ***H2a****: The use of systems that support both convergent and divergent thinking will result in a greater number of ideas being produced for a given creative task than the use of systems that support only convergent thinking.*

> ***H2b****: The use of systems that support both convergent and divergent thinking will result in more novel and purposeful (i.e., creative) ideas being produced for a given creative task than the use of systems that support only convergent thinking.*

In addition, we deem it relevant to test whether the use of a system that supports convergent and divergent thinking will result in higher creative performance than using "pen and paper." This test acts as a control for the effect of software support on creativity. Correspondingly, we state that:

> ***H3a****: The use of systems that support both convergent and divergent thinking will result in a greater number of ideas being produced for a given creative task than the use of no software support.*

> ***H3b****: The use of systems that support both convergent and divergent thinking will result in more novel and purposeful (i.e., creative) ideas being produced for a given creative task than the use of no software support.*

5. Proposed Empirical Evaluation

In addition to the testable hypotheses, we will now discuss how the proposed design theory can be tested and further evaluated. We suggest using both nomothetic and ideographic research strategies. In this line of thinking, we first explicate an exemplary experimental design to test the above hypotheses, and then describe how case research can provide insights into how a system based on the proposed design theory is used in an organizational context. Both strategies of inquiry we see as being suitable to study creativity: While experimental designs allow using various controls to reduce the complexity surrounding creativity to a manageable level (Runco & Sakamoto, 1999), case research is particularly suitable to study creativity from a systems perspective and, thus, view creativity as an organizational rather than an individual phenomenon (Csikszentmihalyi, 1999). At this, we do not claim exhaustiveness; there are other strategies of inquiry that may contribute to evaluating the proposed design theory.

5.1. Exemplary Experimental Design

Following prior studies on creativity support, we propose to test the above stated hypotheses through a laboratory experiment (MacCrimmon & Wagner, 1994; Malaga, 2000; Massetti, 1996). One way to do so is a 1x4 factorial design where four groups of subjects will complete the same task, each using one of the four treatments: (1) paper and pen, (2) software that supports divergent thinking, (3) software that supports convergent thinking, and (4) software that supports both convergent and divergent thinking.

5.1.1. Software Use

The presented expository instantiation can be used for the treatments in the experiment. As it supports both convergent and divergent thinking, three configurations of the tool are used: One that implements the full set of constructs and principles meant to address the design requirements for both divergent and convergent thinking (C.1, C.2, C.3 as well as D.1, D.2, D.3), one that primarily implements the constructs and principles related to divergent thinking (D.1, D.2, D.3), and one that focuses on the constructs and principles related to convergent thinking (C.1, C.2, C.3). Using the same software platform for all treatments, instead of three individual tools, contributes to the internal validity of the experimental results. This way, we can rule out a number of factors related to the software (e.g., usability, design, performance) that may cause effects on the dependent variables.

5.1.2. Subjects

Subjects are randomly assigned to one of the four treatments. In cases where the subjects are not familiar with the software, they receive training on how to operate it. As will be explained below, the baseline creativity for each of the individuals is determined prior to the actual experiment.

5.1.3. Experimental Task

As indicated by Haines and Amabile (1988), tasks should be selected that do not require specific knowledge or training in order to decrease the potential for response bias (also compare Massetti, 1996). Promising examples of experimental tasks that leverage the data we described in the section on our prototypical instantiation include the generation of ideas for a location for a TV ad or a location for a sitcom. Of course, a broad number of alternative problem solving tasks exist. An overview of tasks that have been used in other studies can be found in MacCrimmon and Wagner (1994).

5.1.4. Variables and Measures

The one independent variable of the experiment is the support each individual will use in order to generate creative ideas, that is, (1) paper and pen, (2) software for convergent thinking, (3) software for divergent thinking, and (4) software for both convergent and divergent thinking. The two dependent variables are the number of ideas generated (quantity) and the level of creativity of the generated ideas (quality). While the first one can be objectively measured, the latter will require a rating by experts. We propose to involve two to three experts in the study who will rate the quality of the creative ideas generated in terms of novelty and purposefulness on a Likert scale. Of course, the selection of experts will depend on the experimental task. As indicated earlier, novelty and value (i.e., purposefulness) have been discussed in prior literature as measures to determine the level of creativity (MacCrimmon & Wagner, 1994). To aggregate these measures into one variable (i.e., level of creativity), most studies use simple averaging techniques.

5.1.5. Experimental Procedures

Massetti (1996) describes an experimental procedure based on two sessions that may be used in order to test the hypotheses. In a first session, subjects are trained in thinking more creatively. In this session, among other things, the importance of creativity for business scenarios is explained and examples are provided, where organizations have used creativity in order to become more successful. After the discussion, the baseline creativity of each subject is measured using a pen and paper creativity test. Appropriate creativity tests focusing on divergent thinking include the Torrance Test for Creative Thinking (Torrance, 1958) and Guilford's Alternate Uses Task (Mind Garden, 2011); potential tests for measuring convergent thinking skills include the Insight Problems Test (Dow & Mayer, 2004) and the Remotes Associations Task (Mednick & Mednick, 1967). In a second session, subjects in each of the software treatments receive an introduction to the corresponding configuration of the software. Once the subjects feel comfortable using the software, they are given the task. Subjects belonging to the control group will have to solve the same task only using a pen and a blank sheet of paper.

5.2. Exemplary Case Study Design

While we deem laboratory experiments suitable to validate the proposed design theory through testing the proposed hypotheses, the mere evaluation in such artificial settings may receive some criticism. First, it has been argued that there are problems with drawing conclusions from the results of laboratory experiments on individual creativity (Williams & Yang, 1999): In organizational settings, individuals do not typically work in isolation but in groups. Consequently, individuals may not express the same creativity in a lab setting. Besides, it is questionable that good performance in a laboratory situation also means good performance in real-world scenarios. Second, it will be necessary to investigate how the proposed system design is used in organizational settings. Specifically, it will be interesting to learn about potential unintended consequences and side effects. One may, for instance, speculate that using the proposed class of systems may contribute to individual creativity but, at the same time, lead to less group work and, hence, negatively impact organizational creative performance. In order to gain deeper insights into these issues, we consider case studies an appropriate strategy of inquiry. Case study research "examines a phenomenon in its natural setting, employing multiple methods of data collection to gather information from one or a few entities (people, groups, or organizations)" (Benbasat, Goldstein, & Mead, 1987, p. 370). In the following, we briefly discuss the units of analysis, site selection, data collection, and data analysis (Benbasat et al., 1987).

5.2.1. Units of Analysis

The unit of analysis is a creative work system. Work systems, in general, are systems in which human participants and/or machines perform work using information, technology, and other resources to produce products and/or services for internal or external customers (Alter, 2010, p. 202). Consequently, in our case, such work system will comprise actors who use IT in an organizational setting in order to generate products and/or services that are novel and purposeful, that is, creative.

5.2.2. Site Selection

In the literature on creativity, it has been discussed whether the creative process differs across different industries (Lubart, 2001). Consequently, it will be interesting to evaluate the proposed system design in different real-world scenarios. In this line of thinking, a multi-case design appears promising to investigate both similarities and differences in the use of the proposed class of systems across different settings. Thus, we hope that a multiple-case design will provide additional insights into the type of settings that may particularly benefit from IT that supports divergent and convergent thinking in creative work. Due to the nature of our proposed class of systems, the (re)use of existing knowledge should play a vital role in the creative process under study. Potential fruitful settings include TV or film production firms, VFX studios, advertising agencies, architecture offices, R&D departments, and research institutions.

5.2.3. Data Collection and Analysis

In order to investigate the use of IT for divergent and convergent thinking in real-world settings, we suggest the use of different methods of data collection. Interviews, for instance, will allow the researcher to gain an in-depth understanding of how users perceive the system and also to consider historical information on the usage (Creswell, 2009). Observations, in particular, will allow researchers to also notice unusual or unexpected events, such as unintended consequences and side effects of using IT systems for divergent and convergent thinking (Creswell, 2009). One could even think about collecting audiovisual materials, as this is a particularly unobtrusive method to collect data that may be capable of capturing the dynamics and interactions in creative group work. Collecting different types of data will lead to a strong substantiation of the study findings: The data can then be coded and analyzed, and conclusions with regard to using the proposed class of systems can be drawn.

6. Limitations

This study has some limitations. Most notably, research from different fields, including psychology and organization theory, has shown that the conditions under which creativity takes place significantly impact creative performance (e.g., Edmonds et al., 2005). Other relevant factors include personal traits, abilities, and the preferred working styles of involved people. This complexity, which is reflected in comprehensive models of organizational creativity (e.g., Woodman et al., 1993), inhibits the development of an IT system that provides an appropriate solution under all circumstances (Lubart, 2005; Lubart, 2001; Sternberg, 2005). Besides, the proposed design theory rests on a primarily conceptual level. As is typical for studies at the interception of the information systems and the human-computer interaction discipline, the actual implementation and issues of interface design primarily serve as a proof of concept (Zhang, Benbasat, Carey, Davis, Galletta, & Strong, 2002); the focus of this research is on the theoretical underpinnings of core constructs and principles of form and function for effective IT support for creative work. However, an abundant body of research evidences that the graphical design of user interfaces is an important success factor in the overall design of IT systems; and this especially holds true for IT support in creative work (Burleson & Selker, 2002; Thomas et al., 2002). Hence, in order to transfer our approach into a running system, the design of the graphical user interface needs further attention.

7. Conclusion

We cannot command creativity. Yet, several decades of research give good reasons to believe that there are techniques and working conditions that favor the emergence of creative ideas (Hewett, 2005). Although ambivalent in effect, knowledge plays a central role in any endeavor of a creative nature. “Even though previous experience or knowledge could lead to a ‘functional fixedness’ that prevents individuals from producing creative solutions, on balance it is hard to conceive of any creative behavior that is somehow ‘knowledge free’” (Woodman et al., 1993, p. 301). Also, IT can be part of a working environment that encourages creativity or, at least, does not get into a user’s way when striving for creativity (Hewett, 2005).

Against this background, the present study introduces a design theory that informs the development of IT systems that enhance an individual’s creative performance by supporting divergent and convergent thinking in relation to knowledge provision. The development of an IS design theory constitutes an “important theoretical contribution, because it both provides guidance to developers and sets an agenda for academic research” (Markus et al., 2002, p. 180). On the one hand, the theory can inform software engineers in their efforts to design IT to be used for creative problem solving. On the other hand, the study bears a theory that we hope will initiate and guide future research. Our research is grounded in different kernel theories and focuses on the simultaneous support of convergent and divergent thinking, both of which are central to creative cognition. It addresses all components of a design theory as proposed by Gregor and Jones (2007) and also presents research designs for an empirical evaluation. Table 3 exhibits how we consider the different theory components in the present study.

Table 3. Anatomy of the Developed Design Theory

Design theory component	Reflection in this design theory
(1) Purpose and scope	The aim of the presented design theory is to provide prescriptions on the development of a class of IT systems that support creative work by knowledge provision. The design is tailored to support both convergent and divergent thinking processes.
(2) Constructs	Knowledge items, tags, tag trees, and associative links.

Table 3. Anatomy of the Developed Design Theory (continued)

Design theory component	**Reflection in this design theory**
(3) Principles of form and function	Means for supporting convergent (e.g., tag trees, filters) and divergent (e.g., generation of intra- and inter-domain stimuli) thinking in creative work are defined.
(4) Artifact mutability	Tags and tag trees are highly domain-dependent and have to be tailored to the specific socio-economic context. Even in a given context, they will evolve over time as the system's knowledge base grows and new tasks and users are supported.
(5) Testable propositions	Hypotheses are formulated to test whether the implementation of the proposed constructs and principles of form and function for supporting divergent and convergent thinking result in higher creative performance (in terms of quantity and quality of ideas) compared to software that only supports one of these cognitive processes and to no software support. We present the design of a laboratory experiment appropriate for empirically testing the stated hypotheses. In addition, we outline a case study design to investigate the effects of the proposed system design in its natural setting.
(6) Justificatory knowledge	Design requirements are derived from different kernel theories from the field of human cognition as well as related literature on creativity support.
(7) Principles of implementation	Two implementation principles are suggested: leveraging existing internal and external data sources and motivating user-generated content.
(8) Expository instantiation	A prototypical instantiation is presented for elucidating the different constructs and principles of form and function in the course of the example case of location scouting.

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Appendix

Formal Specification of Constructs

I is a finite set of items.

T is a finite set of tags.

N is a finite set of nodes.

$TT \subseteq \{tt \in \mathrm{P}(N) \setminus \varnothing\}$ is a finite set of tag trees.[1]

$NN \subseteq \{N \times N\}$ is a finite set of direct subordination relations between nodes.

$IT \subseteq \{I \times T\}$ is a finite set of item assignments to tags.

$l_{NT} : N \to T$ is a function that maps each node to its tag.

$II \subseteq \{I \times I\}$ is a finite set of item assignments to items, that is, links between items.

For these core constructs the following restrictions form a valid configuration:

- Every node is the sub node of no more than one other node, that is,

$$\forall n_{\text{sub}} \in N : \left|\left\{nn \in NN \mid \exists n_{\text{sup}} \in N : nn = \left(n_{\text{sup}}, n_{\text{sub}}\right)\right\}\right| \le 1$$

- All nodes belong to a tag tree, that is, $\forall n \in N : \exists tt \in TT : n \in tt$

- All tag trees are acyclic, that is, $\forall \left(n_i, n_j\right) \in NP : n_i \ne n_j$

- There is a navigation path between every pair of nodes of a tag tree, that is,

$$\forall tt \in TT, \forall n_i, n_j \in tt, n_i \ne n_j : \exists \left(n_i, n_j\right) \in NN \vee \exists \left(n_j, n_i\right) \in NN$$

Formal Specification of Principles for Convergent Thinking

A node filter restricts the shown items to the subset of items that is assigned to this node:

$$l_{NF}(n) := \left\{i_i \in I \mid \exists it \in IT : it = \left(i_i, t\right) \wedge l_{NT}(n) = t\right\}$$

A branch filter restricts the set of displayed items to the subset of items that are assigned to either the node itself or all nodes of the sub branch that starts with the given node:

$$l_{BF}(n) := \bigcup l_{NF}\left(n_i\right) : \left(n, n_i\right) \in NN^{+} \vee n = n_i$$ [2]

[1] $\mathrm{P}(N)$ denotes the power set of N

[2] NN^{+} denotes the transitive closure of the relation NN, that is, $\left(n_1, n_i\right) \in NN^{+} \Leftrightarrow \exists i \ge 2 : \exists n_1, \ldots, n_i \in N : \forall j \in 1, \ldots, i-1 : \left(n_j, n_{j+1}\right) \in NN$

Formal Specification of Principles for Divergent Thinking

Items serve as links between tag trees as an item may be assigned to different tags in different trees. If the user is focusing on a specific item, the set of all other nodes to which that item is assigned can be derived in accordance to the following formal expression:

$$l_{IRN}(i) := \{n_i \in N \mid i \in l_{NF}(n_i)\}$$

Tags constitute hubs in the classification structure as they can be related to several nodes in different tag trees. For a specific node, a set of other nodes with the same tag is defined as follows:

$$l_{NRN}(n) := \{n_i \in N \mid l_{NT}(n) = l_{NT}(n_i)\}$$

Exploiting item-tag assignments, a list of related tags to a given node can be displayed. Here, relatedness is determined on the basis of the relative item intersection between a node in focus and all other nodes of the navigation structure. For a node n the maximal relative item intersection with the nodes n_j is defined as:

$$\max_{n_j \in N}\left\{\frac{\left|l_{NF}(n) \cap l_{NF}(n_j) \setminus l_{NF}(n)\right|}{\max\left\{\left|l_{NF}(n)\right|, \left|l_{NF}(n_j)\right|\right\}}\right\}$$

Finally, a list of items that are connected via user-generated links to the item in focus can be displayed according to the following expression:

$$l_{IRI}(i) := \{i_i \in I \mid \exists ii \in II : ii = (i_i, i) \vee ii = (i, i_i)\}$$

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